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DATE:	February 10, 2003	**Action Item #: 1636**
RE:	AMS Magnetic Field Strength to SPDM Arm During S3 RPCM R&R	
CC:	Gene Cook/OZ, Bob Miley/OZ, Victor Sanders/TBE, William Corley/TBE, Richard Golick/OZ, Trent Martin/LM, Ken Bollweg/LM, Monica Visinsky/OSS, Shakeel Razvi/OM, RS Library	
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The MAGIK Robotic Analysis Team has determined approximate Alpha Magnetic Spectrometer (AMS) magnetic field strengths acting on the Special Purpose Dexterous Manipulator (SPDM) right arm during the S3 RPCM 3 and 4 Remove and Replace (R&R) operations. This memo is a follow-on to MAGIK Action Item 1608, "Robotic Ops Near or Inside the AMS Magnetic Field" which identified a violation of the AMS 6 Gauss Envelope during the S3 RPCM 3 and 4 R&R. The envelope was violated by the stabilization arm (the right arm in this case) during the approach and the grapple of S3 H Fixture #2. The Systems Engineering Working Group (SEWG) asked the MAGIK Team to determine a better approximation of the field strength acting on the SPDM arm during these operations.

The SPDM body does not need to relocate and the stabilization arm can use the same configuration to perform both the S3 RPCM 3 and the RPCM 4 R&R. However, two configurations for the stabilization arm were assessed in this analysis to determine if there is a significant change in magnetic field strength for alternate configurations.

Assumptions:

- This analysis addresses kinematic feasibility by analyzing manipulator configurations during robotic tasks. These manipulator configurations are driven by numerous constraints such as clearance with Orbiter or ISS structure, and manipulator joint limits and singularities. Areas not addressed in this document – lighting, EVA/EVR tasks, viewing, thermal and/or pressure effects on elements, and dynamics – could have a significant influence on manipulator configurations and overall feasibility.
- 3D graphical models used in this analysis are a result of the MAGIK Team's "best efforts" to obtain/create accurate models reflecting actual volumetric dimensions of the various ISS elements. "Best efforts" include obtaining models directly from the ISS CAD Modeling Team, the hardware designers, or a 3rd party (a source other than the hardware designers), or creating models from hardware designer or customer provided drawings/information.
- Specific model pedigrees may be obtained from the MAGIK Team upon request.
- The trajectories and specific robot joint angles used in this analysis are not necessarily the final configurations that will be used on-orbit.
- The center of the magnetic field is the origin of the AMS graphical model defined in Figure 1.

- The magnetic field X-axis is parallel to the orbiter X-axis when the AMS is manifested.
- The magnetic field Y-axis is parallel to the orbiter Y-axis when the AMS is manifested.
- The Gauss values given in this memo are based on a 12,000-point magnetic field database supplied by the AMS designers.
- The Gauss values given in this memo are representative of specific SSRMS and SPDM joint configurations for the given operations. Alternative joint configurations will yield different, but similar, results.
- Since the MAGIK Team does not know the database pedigree or how the data was obtained, whether experimentally or by analysis, and whether there is any error, uncertainty, or margin built into the data, the MAGIK Team cannot draw any definitive conclusions from this report.

Approach to Determine Magnetic Strength Acting on SPDM Arm:

1. Configure the SSRMS and SPDM to perform the robotic operation.
2. Use the MAGIK Enigma tool to determine the closest point on each SPDM arm joint to the AMS center.
3. Use the AMS database of magnetic field strengths to determine the database point closest to the MAGIK Enigma point.
   a. The database X, Y, and Z spacing is in increments of 25 centimeters.
   b. The closest database point may or may not be farther away from the center of the magnet than the MAGIK Enigma point.
4. Record the AMS magnet strength given in the database for the database point closest to the MAGIK Enigma point.
5. Round the MAGIK Enigma point X, Y, and Z coordinates down to the nearest multiple of 25 centimeters.
   a. This was done to insure the database point is closer to the magnet than the MAGIK Enigma point. This method adds a degree of conservatism to the process.
6. Record the AMS magnet strength given in the database for the rounded coordinates.
7. Repeat Steps 1-6 for an alternate arm configuration. Perform an arm pitch-plane change to achieve the alternate configuration. Label this configuration "Case 2."

Summary:

The SPDM right arm was shown to violate the AMS 6 Gauss envelope while approaching and grasping the S3 H Fixture #2 for stabilization during the S3 RPCM R&R in MAGIK Action Item 1608. This action approximates the exact magnetic strength acting on the arm during this operation.

Table 1, below, shows the worst-case, approximate magnetic field strength on each joint during the robotic operation. These values were determined using the above approach and represent the most conservative method (Steps 5 & 6).   The values are also the worst case, of two cases assessed, for grasping the same H Fixture.

Table 2 shows the detailed data for the two cases assessed. In each of the two cases, the SPDM right arm is grasping the S3 H Fixture #2, but with a slightly different configuration.

Table 1: Summary of Magnetic Field Strength on SPDM

	Magnetic Field Strength (Gauss) at:	
	Approach to Grapple	Grapple H Fixture
Wrist Roll	5.8	5.8
Wrist Yaw	5.0	6.4
Wrist Pitch	8.4	8.0
Elbow Pitch	8.2	8.4
Shldr. Pitch	6.1	6.9

Table 2: Detailed Data for SPDM Approach and Grasp of S3 H Fixture #2

Case 1	AMS center to SPDM Rt. Arm:	Location of point found in Enigma (wrt AMS Coordinate Frame):			Absolute value of Enigma point (Since only positive points were given in the database)			Closest Data Point			Dist. from Enigma Point to Data Point	Gauss Level at that point	Data Point using rounded Enigma Point			Dist. from Enigma Point to Data Point	Gauss Level at that point
		X (cm)	Y (cm)	Z (cm)	X (cm)	Y (cm)	Z (cm)	X (cm)	Y (cm)	Z (cm)			X (cm)	Y (cm)	Z (cm)		
SPDM Rt. Arm Approach to Grapple Stabilizing H Fixture	Wrist Roll	-106.2	-271.7	-252.6	106.2	271.7	252.6	100	275	250	7.5	4.8	100	250	250	22.7	5.8
	Wrist Yaw	-119.5	-301.2	-227.9	119.5	301.2	227.9	125	300	225	6.3	4.8	100	300	225	19.8	5.0
	Wrist Pitch	-84.0	-279.6	-223.5	84.0	279.6	223.5	75	275	225	10.2	6.4	75	275	200	25.6	8.4
	Elbow Pitch	-82.2	-321.4	-189.0	82.2	321.4	189.0	75	325	200	13.6	5.1	75	300	175	25.6	8.2
	Shldr. Pitch	-119.3	-381.7	-142.3	119.3	381.7	142.3	125	375	150	11.7	4.1	100	375	125	26.8	4.8
SPDM Rt. Arm Grasp Stabilizing H Fixture	Wrist Roll	-103.5	-260.1	-264.1	103.5	260.1	264.1	100	250	275	15.3	4.3	100	250	250	17.7	5.8
	Wrist Yaw	-106.9	-283.6	-251.0	106.9	283.6	251.0	100	275	250	11.1	4.8	100	275	250	11.1	4.8
	Wrist Pitch	-83.8	-255.0	-243.0	83.8	255.0	243.0	75	250	250	12.3	6.0	75	250	225	20.7	8.0
	Elbow Pitch	-82.6	-295.7	-206.3	82.6	295.7	206.3	75	300	200	10.8	6.5	75	275	200	22.9	8.4
	Shldr. Pitch	-121.7	-359.5	-158.0	121.7	359.5	158.0	125	350	150	12.9	5.3	100	350	150	25.0	5.5

Case 2	AMS center to SPDM Rt. Arm:	Location of point found in Enigma (wrt AMS Coordinate Frame):			Absolute value of Enigma point (Since only positive points were given in the database)			Closest Data Point			Dist. from Enigma Point to Data Point	Gauss Level at that point	Data Point using rounded Enigma Point			Dist. from Enigma Point to Data Point	Gauss Level at that point
		X (cm)	Y (cm)	Z (cm)	X (cm)	Y (cm)	Z (cm)	X (cm)	Y (cm)	Z (cm)			X (cm)	Y (cm)	Z (cm)		
SPDM Rt. Arm Approach to Grapple Stabilizing H Fixture	Wrist Roll	-105.2	-271.8	-252.4	105.2	271.8	252.4	100	275	250	6.6	4.8	100	250	250	22.5	5.8
	Wrist Yaw	-120.1	-301.2	-228.1	120.1	301.2	228.1	125	300	225	5.9	4.8	100	300	225	20.4	5.0
	Wrist Pitch	-81.9	-277.3	-222.2	81.9	277.3	222.2	75	275	225	7.8	6.4	75	275	200	23.4	8.4
	Elbow Pitch	-88.5	-315.9	-185.3	88.5	315.9	185.3	100	325	175	17.9	6.1	75	300	175	23.3	8.2
	Shldr. Pitch	-136.4	-368.9	-139.4	136.4	368.9	139.4	125	375	150	16.7	4.1	125	350	125	26.4	6.1
SPDM Rt. Arm Grasp Stabilizing H Fixture	Wrist Roll	-102.4	-260.2	-263.9	102.4	260.2	263.9	100	250	275	15.3	4.3	100	250	250	17.4	5.8
	Wrist Yaw	-87.9	-287.9	-247.4	87.9	287.9	247.4	100	300	250	17.3	3.9	75	275	225	28.9	6.4
	Wrist Pitch	-77.1	-257.1	-236.1	77.1	257.1	236.1	75	250	225	13.3	8.0	75	250	225	13.3	8.0
	Elbow Pitch	-88.4	-291.5	-202.4	88.4	291.5	202.4	100	300	200	14.6	6.3	75	275	200	21.4	8.4
	Shldr. Pitch	-139.9	-347.9	-155.2	139.9	347.9	155.2	150	350	150	11.6	4.9	125	325	150	27.8	6.9

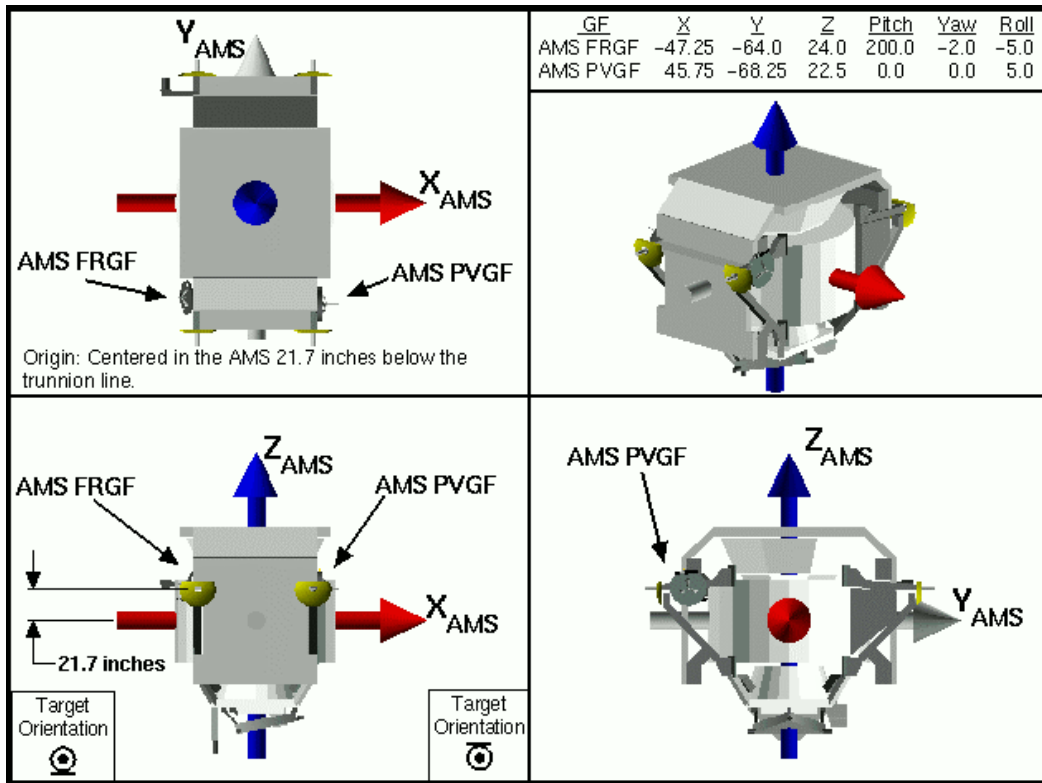| GF	X	Y	Z	Pitch	Yaw	Roll
AMS FRGF	−47.25	−64.0	24.0	200.0	−2.0	−5.0
AMS PVGF	45.75	−68.25	22.5	0.0	0.0	5.0

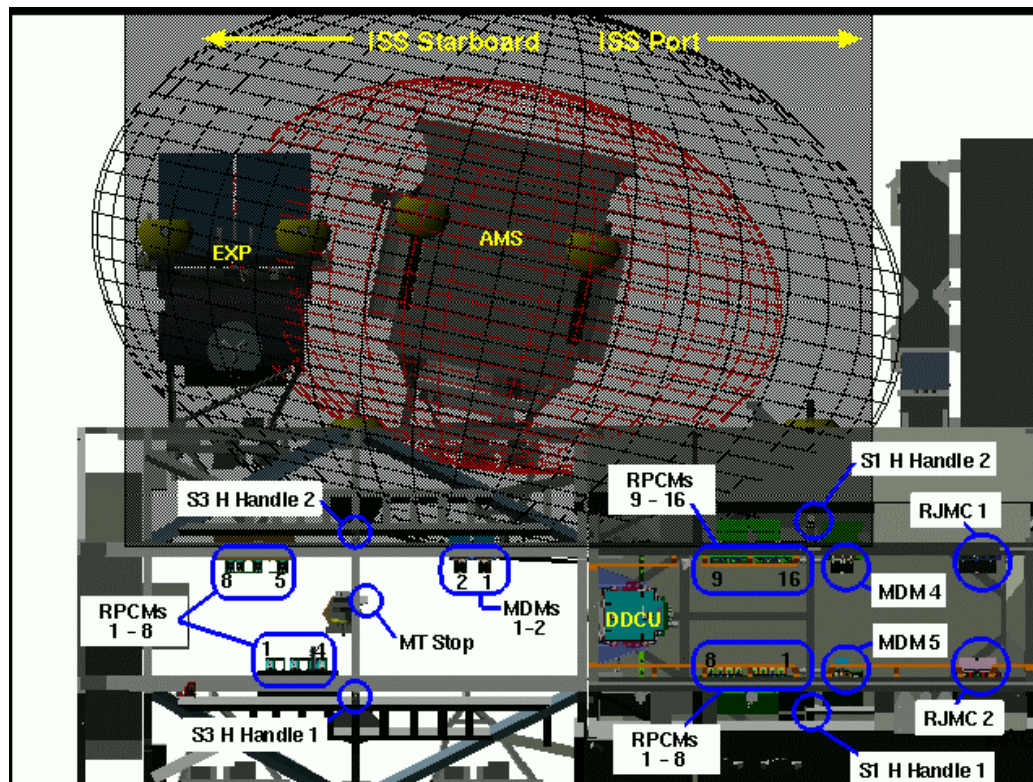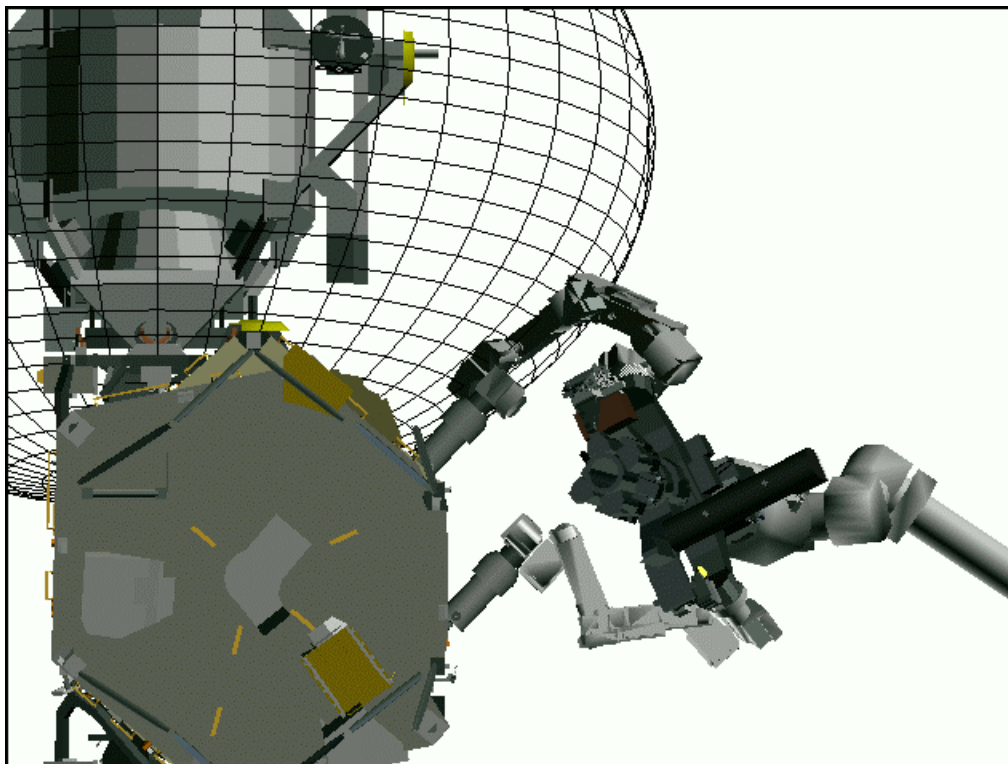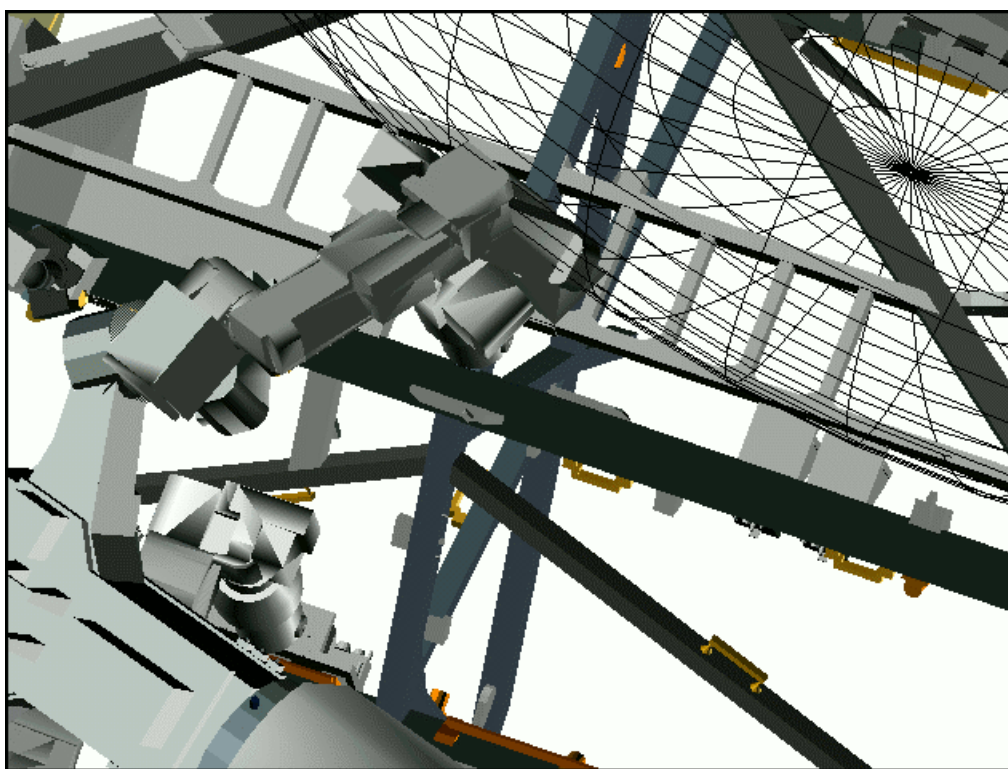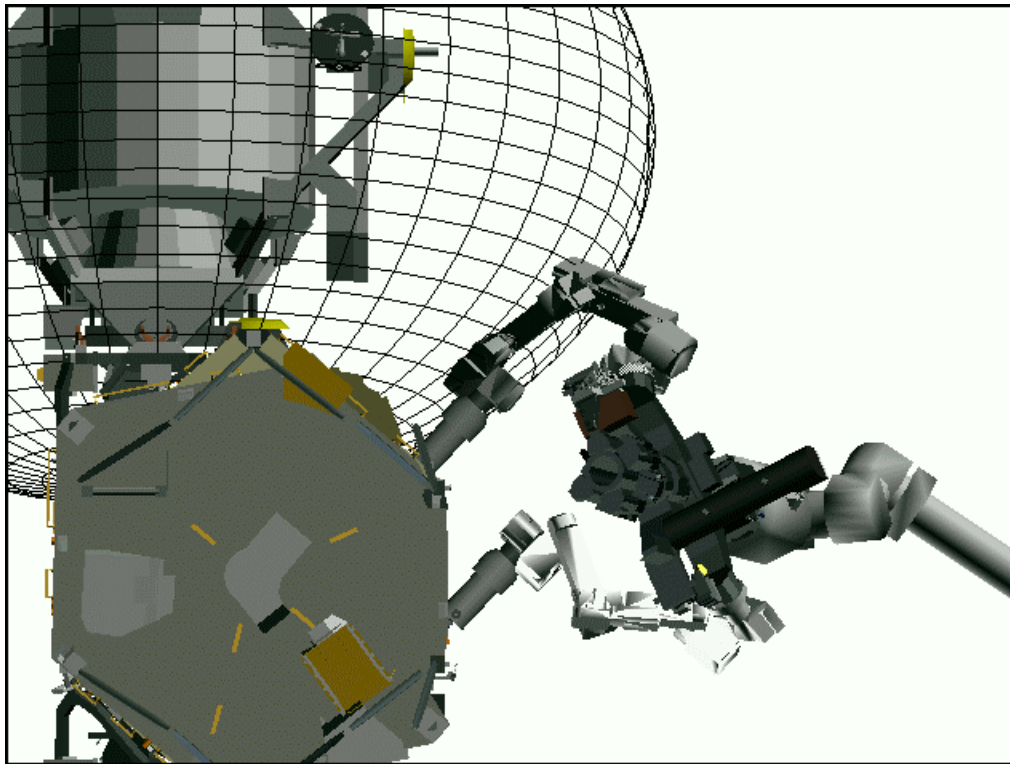**Figure 1: AMS Origin and Center of Magnetic Field**

Figure 2: AMS Magnetic Field Skins and Surrounding S1/S3 ORUs
ISS Front View

Figure 3: SPDM Access to S3 RPCM – Case 1
ISS Starboard View

Figure 4: SPDM Access to S3 RPCM - Case 1
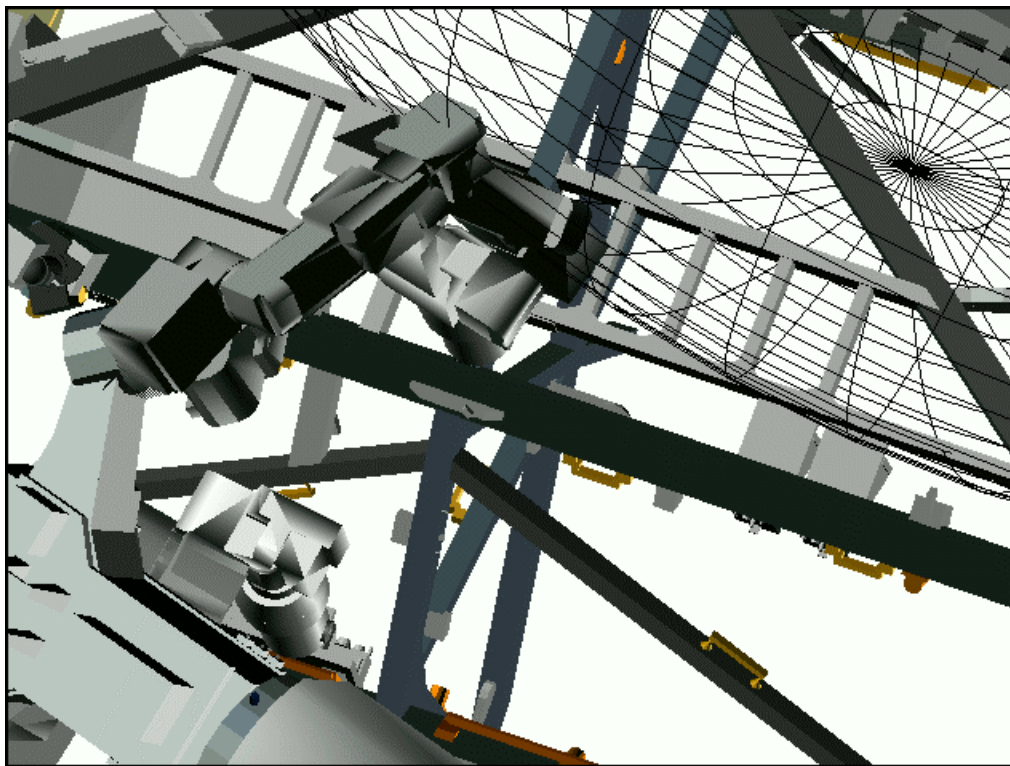**Isometric View Looking ISS Nadir-Aft**

**Figure 5: SPDM Access to S3 RPCM – Case 2
ISS Starboard View**

**Figure 6: SPDM Access to S3 RPCM - Case 2
Isometric View Looking ISS Nadir-Aft**